mF

JPRS: 4297

3 January 1961

THE PROBLEM OF PREDICTING THE APPEARANCE OF PESTS AND DISEASES OF AGRICULTURAL PLANTS

By I. Ya. Polyakov

- INTRABLOC -

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
1636 CONNECTICUT AVE., N.W.
WASHINGTON 25, D. C.

F O R E W O R D

This publication was prepared under contract by the UNITED STATES JOINT PUBLICATIONS RESEARCH SERVICE, a federal government organization established to service the translation and research needs of the various government departments.

JPRS: 4297

CSO: 1249-S

THE PROBLEM OF PREDICTING THE APPEARANCE OF PESTS AND DISEASES OF AGRICULTURAL PLANTS

- Intrabloc -

[Following is the translation of an article by Prof I. Ya. Polyakov in Trudy VIZR (Work of the All-Union Institute of Plant Protection), No 12, 1958, pages 203-219]

(Based on material of the Eighth International Conference on Plant Protection and Quarantine. This article gives information on contemporary methods of solving problems of predicting the appearance of plant blights and diseases in the people's democracies).

Problems of the prediction of the appearance of blights and diseases of agricultural crops were generally discussed for the first time in an international conference at the Eighth International Conference on Plant Protection and Quarantine, held in 1956 in Peking. Twelve countries participated in this conference: the People's Republic of Albania, the Bulgarian People's Republic, the Hungarian People's Republic, the Democratic Republic of Vietnam, the German Democratic Republic, the Chinese People's Republic, the Korean People's Democratic Republic, the Mongolian People's Republic, the Polish People's Republic, the Rumanian People's Republic, the USSR, and the Czechoslovak People's Republic.

The direction and development of agricultural production is essentially different in these countries; their prediction services have different histories and unequal practical significance. Along with this the material examined at the Eighth International Conference allows the contemporary status of the problem of predicting plant blights and diseases, its theoretical bases and practical direction to be sufficiently thoroughly evaluated.

Tasks of the Agricultural Crop Blight and Disease Development Prediction Service

The Eighth International Conference on Plant Protection and Quarantine established that the prediction service in each country must

carry out four assignments. (Communique of the Eighth International Conference on Plant Protection and Quarantine, 1956, Publishing House of the Ministry of Agriculture, Chinese Peoples Republic, in Russian, Chinese, German, and English.)

The first assignment: The prediction service on the basis of broad ecological-faunal and ecological-floristic research and analysis of statistical data determines the regions of a country in which agricultural plants are subject to constant or periodic damage from the blights and diseases. As a result of this research the approximate average minimum and maximum annual requirement in poison chemicals and plant protection equipment is determined on a government or state scale. On the basis of this, measures for the domestic production or import of poison chemicals and plant protection equipment and the annual expenditures of labor are then planned.

In general this work is being carried out at the present time by all countries in the socialist camp. However, agricultural production is actively being developed, new regions are being cultivated, and land tillage techniques are changing. In addition, a number of countries have changed from passive protection of crops to radical suppression of blights and diseases, which requires large expenditures over a certain period of time. All this calls for further development in the work of revealing the spread of plant blights and diseases and the determination of zones where some of them are or are becoming economically significant, and where others have lost their significance.

The second assignment: the compiling of predictions of the appearance of individual types of blights and plant diseases for each zone of the country for the next year or, if possible, for a longer period of time. These predictions are above all utilized for the organization of preventive measures with the purpose of warding off the mass appearance and spread of blights and diseases. In addition, such predictions are necessary for the perfection of general state planning activities in plant protection for the year following and the distribution of resources by individual regions of the country.

The third assignment: Working out predictions of the development of blights and insect diseases for a comparatively short period (3 to 15-20 days). These predictions are used to carry out special plant protection measures in such time periods which provide for the most complete destruction of blights and diseases with the least expenditure. As a supplement to the short-term prediction, or in those cases when they cannot be worked out, a warning system for the initial appearances of the blights and diseases is organized. This warning system raises considerably the effectiveness of the destructive measures and decreases their cost.

The fourth assignment: Systematic accounting of harvest losses due to blights and diseases of agricultural plants, an accounting of the general economic significance of blights and diseases, and the economic effectiveness of plant protection measures. (Work methods in evaluating the economic significance of plant blights and diseases were not subject to special examination at this conference. It was

decided to discuss them at the Ninth International Conference with a view to the maximum unification of this work in various countries.)

At the present time the scientific prerequisites for the successful fulfillment of all assignments given to the prediction service have as yet been only poorly worked out. Nor does prediction service organization in individual countries as yet meet present day requirements of agriculture.

In generalizing the experience of countries of the socialist block, the Eighth Conference in its decisions planned the direction which scientific and operational work in predicting was to take. The development of prediction methods must be undertaken in special scientific institutions which are provided with the necessary equipment and highly qualified cadres working in close contact with the operational prediction service. The operational prediction service must be supported by a special network of observation points manned by qualified specialists. The methodical management of its activity is undertaken by scientific institutions to which is also entrusted the compilation of surveys on the spread of blights and diseases and the prediction of their appearance at a future time. In regard to administration, the prediction service points are under the ministries of agriculture of the republics. (These organizational principles are reflected in the organization of the prediction services of the USSR. See Basic Principles of the work of the Calculating and Predicting Service, Publishing House of the Ministry of Agriculture, USSR, 1957.)

Scientific Bases and Methods of the Long-Range Prediction of Plant Blight and Disease Development

The Eighth Conference in its decisions mentioned that the prediction service must be supported by the most recent data on the ecology and physiology of blights and pathogenic agents of plant diseases, on statistical material collected according to rigidly established methods, on the characteristic presence and spreading of blights and diseases in established seasons of the year, and on data on the natural and economic regionalization of the country.

The USSR delegation turned the attention of the conference to the fact that ecological and physiological research must above all ascertain the specific requirements of each species of blight and type of disease for the following conditions: Nourishment, temperature, light, composition of the soil, plant diversity, etc. It is necessary to establish how these requirements change, depending on the stage of the seasonal ontogenetic development of organisms or in individual areas. This part of the research is the most difficult and responsible part of the work in the scientific basing of long-term predictions of the development of blights and diseases. To obtain trustworthy material it is necessary to combine careful laboratory experiments with comparative geographical and comparative stational ecological field research.

The requirements of species for nourishment, heat exchange, and other factors are judged by the reactions of individuals [of the species] or populations of a given species to the concrete combinations of these factors, which are tested by experiment or sufficiently accurately taken stock of in nature. These reactions are expressed in the alteration in weight of the individuals, the tempi of their growth and development, the intensity and level of metabolism, the rapidity of reproduction, the composition of tissues and gonads, and in alterations in other life phenomena. The complexity of such research consists in the fact that the reactions of individuals and populations in experimental conditions are not only determined by the condition of the testing environment but also by those conditions in which proceeded the development of experimental individuals in the past. However these aspects appear only in the result of special additional research. If we take into account that the condition of the medium itself does not always submit to accurate calculation, then it is easy to understand what a large number of factual errors and errors in principle and theory lie in wait for the research worker if he does not evaluate the entire complexity of this assignment from the very beginning.

At the same time it is clear that only by taking into consideration the requirements of individual species toward the environment can be determined accurately the degree of favorableness for each of these concrete ecological conditions (nourishment, temperature, moisture, etc.) which are revealed in individual stages [statsiya], biotypes, or natural and economic regions. Without calculating the requirements of individual species with respect to the environment, it is impossible to accurately evaluate their condition, number, ability to spread from specific combinations of favorable conditions, techniques of crop tillage, and the economic activity as a whole.

A second, no less important, problem is the determination of the regularity of the shifting of ecological conditions by seasons in individual natural and economic regions. Keeping in mind the requirements of specific species for environmental conditions, the state of the most important elements of the environment for the species and their alteration under the influence of natural factors and the activity of man are studied in the comparative geographic plan by seasons and years. This work, in connection with statistical material on the actual spread of a given species of blight or disease, permits the general presentation of the factors which limit or aid their spread to be made essentially more accurate. The research must be carried out in this manner in order to form an opinion of the existing ecological changes of the environment for a species according to determined combinations of annual conditions, the state of vegetation, and economic or agrotechnical measures. These indices are in essence the criteria for the prediction of periods of appearance and the spread of this or that species of blight or plant disease.

Thus in the result of the all-embracing research in the ecology and physiology of species are revealed the external, easily appreciable

indices of the state of the ecological environment, according to which we may judge the degree of favorableness or unfavorableness of the surroundings for the development of a certain species of blight or disease in a given season or given year. However, as experience has shown, this is still not sufficient for the compilation of long-range predictions. Practically speaking, we can judge the favorability of the past and present period but the prediction must also judge the future. The future ecological conditions are in some measure determined by agrotechnical plans and the economic activity of man, for plant diseases and blights they frequently have important though subordinate significance. The weather is the most important influence (the condition of moisture, temperature, and especially its fluctuations, and other elements) both directly and indirectly (through the food base).

Forecasting the weather, especially over a long period of time, can still not be considered reliable. For this reason also, the long-range predictions of the development of blights and diseases seems impossible. This is exactly how the problem presents itself in a number of countries, in particular the GDR, where the problem of predicting the development of blights and diseases has been worked on for more than 60 years.

On the other hand it has already been repeatedly observed, in particular in the USSR and later in other countries, that, for example, the ordinary field mouse (Microtus arvalis Pall.) under conditions favorable for this species (according to external indices) dies out or does not multiply, but multiplies under unfavorable conditions, their number continuing to increase for some time. Such facts are also well-known in regard to other species of rodents and several species of insects. At first glance these facts can undermine all our presentations on the influence of environment on the condition and number of insects. In the recent past they caused the influence of ecological conditions on the dynamics of species number to be ignored, which gave birth even to the theory of the endogenic (internal) factor of the dynamics of species number. The supporters of this theory maintain that historically the species has worked out the characteristic of automatically controlling its own number; when it grows to a certain stage multiplication ceases independently of ecological conditions; when the number is low, multiplication becomes more intensive (with regard to ecological environment). Multiplication is more intensive on the periphery of the area of the species than within the area.

This problem was cleared up only during the past few years, when a study of its applicability was utilized in solving the problem of the dynamics of species number. Special research conducted in the USSR (All-Union Institute of Plant Protection) on mice (Microtus) indicated that the reactions of the individuals of a species to specific ecological conditions were really unequal and did not always indicate the degree of their objective favorability for the species. It was established that these reactions depend on the physiological characteristics of organisms which took form under the infleunce of those ecological conditions in which their development proceeded in the past.

If the population of the common mouse lived through a summer period of drought and was brought up under high temperature conditions and in the presence of insufficient succulent forage, then in the autumn the multiplication of these rodents will be repressed and their number may be lowered in spite of the existence of favorable weather and feeding conditions. If the population has developed in favorable ecological conditions, then even the influence of unfavorable surroundings will not at once negatively affect its state. Over a period of time the number of the species will increase although the attendant ecological conditions may be unfavorable.

It may be said that the reactions of the populations of species to specific ecological conditions is determined by the conditions of its vitality (by the condition of its physiological characteristics). The latter is created by those conditions of the environment in which the development proceeds of the individuals of the species which make up the population in the preceding season or seasons. Consequently, in order to correctly understand the reaction of the population of a species to its conditions of life in the future, it is necessary to correctly evaluate the degree to which these conditions conform to those which existed in past periods. This circumstance is extremely important for prediction.

At the present time in making predictions, our dependence on unknown future ecological conditions is being significantly decreased, and along with this the reliability of prediction becomes dependent on the many-sided analysis of ecological surroundings (for the past and present periods) which easily lend themselves to calculation and analysis. Thus the facts which at first seemingly weakened the position of science in solving the prediction problems, have now, when science has looked into the biological mechanisms, strengthened its position.

In considering these mechanisms, a method of predicting the number of rodents was worked out in the USSR, with the aid of which is established the specific character of the species of these blights and the features of the ecological conditions in different natural and economic regions. (See our article "Biological bases for combatting Rodents -- Destroyers of Field Crops and Pasture lands." in the present collection.)

All these factors exist to suppose that the revealed general biological mechanisms which serve as prerequisites for the long-range predictions of the number of several species of rodents will have a positive influence on the development of further research into basic principles of predicting insect number.

Various methods are being used at the present time in making long-range predictions of blight number. All of these, in the final result, are based on the establishment of weak points in the existence of species -- ecological factors which limit survival, development, multiplication in fixed seasons of the year, and the disclosure of the actual spread and number of individuals after these seasons.

There have still not been ascertained for many species the conditions which limit their survival, development, and multiplication. In these cases predictions are based on investigation and calculations carried out several times per year according to an established system.

We shall present several examples from the experience of the countries participating at the Eighth International Conference to illustrate the most widely used methods of long-range prediction of harmful insect numbers.

A very important and long studied subject is the migratory locust (Locusta migratoria L.). In China historical records have been preserved which permit us to determine all mass appearance cases of this species in the course of 2,600 years. More than 800 disasters from invasions by this locust have been noted for this period. However, the scientific basis for predicting the appearance of this species was worked out only recently.

The subspecies of the migratory locust, the Locusta migratoria manilensis Meyer, is widespread in the Chinese People's Republic. Its breeding sites are concentrated in three types of land areas:

1. Lake and river bottom lands have a fluctuating water level (Lake Hung-chieh located on the border of the contiguous provinces Kiangsu and Anhwei; Lake Wei-shan located between the provinces of Shantung and Khangsu; Lake Hashuhai in Inner Mongolia; bottom land of the Yellow River in the territory of the provinces of Honan and Shantung, and others.)

2. Salty virgin and disused lands near sea coasts (regions contiguous to the Po-hai [Gulf of Chili] in the provinces of Hopei and Shantung, including the districts of T'ang-shan, T'uan-chin, P'eng-hsiang, Haiman, Chang-wei, and others; coastal regions of the Yellow Sea in the norhtern part of the province of Kiangsu).

3. Areas flooded with sewage water or low areas where there is excessive river flooding. Such places adjoin the valleys of the Yung-ting and Yellow Rivers, are in the provinces of Hopei, Honan, and others.

The general ecological characteristic of all types of breeding sites of the locust in the Chinese People's Republic is the alternation of drought-afflicted and especially humid years. On the average during each three year period, one year is extremely drought-afflicted and one year is extremely humid. This leads to a periodic draining of large areas of water, which are then favorable for the laying of locust clutches and the subsequent development of locusts. At the same time an optimum forage base is provided at the expense of moisture-loving grasses, bulrushes, and reeds. These foci cannot be utilized for the cultivation of agricultural crops without special land improvement operations, and for this reason no agrotechnical influence which has a negative effect on locusts is present.

At the present time various sides of the ecology of the Locusta migratoria manilensis Meyer have been sufficiently fully revealed. Much attention has been devoted to a study of the factors which affect the rapidity of multiplication, the development tempi and survival

of locusts in the various phases of ontogenesis, as these aspects, in the final analysis, determine the alteration in their number. It has been established that temperature exerts an essential influence on the rapidity of development of the locusts. They grow rapidly at an optimum high temperature and require less amounts of effective temperature for the completion of their development. At a low temperature, the locusts develop slowly and require large amounts of effective temperature for the completion of development. The ovification threshold of Locusta migratoria manilensis Meyer is 15 degrees. A sum of effective temperatures of 210 degrees is required to complete embryonic development. A sum of effective temperatures of 460 degrees is required to complete the development of the larvae under a temperature of 26-32 degrees; development continues 40-45 days. Effective temperatures amounting to 530 degrees are required at temperatures of 20-28 degrees and development continues 45-60 days. At temperatures of 18-24 degrees (22 degrees on the average), effective temperatures amounting to 580 degrees are required, and larval development continues 75-96 days.

The Locusta migratoria manilensis Meyer can produce from two to three generations in the course of a year, depending on the weather conditions in one region or the other, and to the south of the Nanling Range even four generations have been noted in drought years. One generation per year occurs in certain northern regions.

An increase in the number of generations calls forth an increase in the number of locusts in a given year, but this does not always lead to a high number of them in the following year. As a rule, a large part of the locust larva of the third generation perish, having failed to reach the adult stage. Even those individuals who reach the imago stage usually are not successful in laying locust clutches, as they perish from frosts. The presence of third generation larvae and their condition in a given year is utilized as one of the essential criteria for predicting the number of the Locusta migratoria manilensis Meyer for the following year.

These locusts hatch, as a rule, during the last 10 days of April to 10th and 20th of May. Hatching takes place during the first 10 days of April, in the very early spring, in regions south of the Yang'tze River. If, however, there are frosts, the larvae perish. This aspect is also utilized for predicting the number in a given year.

The water level in the breeding zone is an important factor in the dynamics of number of this particular locust. In drought years (usually under temperature conditions more favorable for locust development than in humid years) the water level in the lakes is lowered and conditions are created over large areas which are favorable for the laying of clutches. For example, in the region of Lake Wei-shan in 1952, there was uncovered a strip 7.5-8 kilometers wide instead of the 2-3 kilometers of normal years, owing to the occasional drought. If the year is humid and the water level is not as low or is lowered only up to autumn, this sharply decreases the areas suitable for

laying locust clutches. As a result the number of locusts will be lower in the following year. This factor is also very essential in making predictions. It has also been established that the summer flooding of areas where locust clutches are laid leads to their complete destruction sufficiently rapidly. Chinese scientists have revealed (Institute of Entomology of the Academy of Scientists, Chinese People's Republic) that at a water temperature of more than 31 degrees under natural conditions locust clutches perish within 40 days. If the temperature of the water does not go above 18 degrees, then in nine months locust larvae hatch from a significantly large part of the clutches. For this reason one very seldom notices mass multiplication of this subspecies in southern regions of China. But here also, for example, a mass appearance of locusts was observed in the province of Kwangsi, in the districts [uyezd in Russian] of Liu-chu, Lo-jung, Ku-hsien, and Pin-hsien.

Droughts are not absolutely favorable for the Locusta migratoria manilensis Meyer. An extreme spring drought such as occurred in the province of Shan'dun in 1955, brought about the destruction of approximately 44 percent of the laid clutches. For this reason, Chinese scientists think it necessary to consider the following in the final judgement of the role of weather conditions in the dynamics of locust number: the actual duration of droughts and floods, at what seasons of the year the droughts and floods occurred, and the temperature prevailing in that period.

The Locusta migratoria malinensis Meyer has many enemies, which in a number of cases considerably reduces its number. In the ovum phase it is destroyed by egg-eaters, larvae of the Spanish fly, and larvae of one of the species of grasshopper bee fly (Bombyliidae). In certain cases the destruction of cluthces by eggeaters reaches 20 percent. In the spring of 1954 in Inner Mongolia over 50 percent of the clutches were destroyed by bee-fly larvae in the breeding site on Lake Ha-Su-hai. Frequently noticed is the extinction of locusts, caused by a mushroom disease (Empusa sp.). There are 18 species of known birds which eat locusts. In several lake regions of the Chinese People's Republic ducks are used to combat locusts. The ducks each consume about one kilogram of locusts per day.

Man's activity can significantly influence the number of these locusts; this activity is directed toward stabilizing the water level of rivers and lakes, and the control of areas which were formerly periodically flooded. Large scale work of this type was planned and is being done in the Chinese People's Republic. It has significance for the radical suppression of harmful locusts.

Thus the ecological research work which has been carried out permits a judgement of the tendencies of locust number alteration. However, in itself this judgement is insufficient for the planning and execution of destructive measures, since for this we must know the areas which are populated by locusts and the density of the population. For this reason the main attention is at the present time being devoted

to uncovering the actual areas which are occupied by locusts, and to determining the density of the populations at various times of the year. It is felt in China that the prediction must be based mainly on investigations and accounting of clutches, larvae, and adult locusts. These three aspects constitute one complex which permits prediction and warning assignments to be carried out.

Investigations are conducted according to a fixed system, beginning with the last 10 days of April and up to the last 10 days of December. They are made by state specialists and their auxiliary personnel, chosen by agricultural cooperatives. The method of investigation and accounting of clutches, larvae, and adult individuals as well as the periods when this work is carried out is subordinated to obtaining for the most important stages of the development of locusts, if possible, complete data on the areas which they occupy, and the condition and number of insects, keeping in mind all the while the ecological conditions. With the support of these data, and considering the further possible alteration, and proceeding from the established ecological surroundings, combatting measures are then planned and realized.

The basic principles of the organization in the Chinese People's Republic of investigating areas occupied by locusts is apparent in the following examples:

If in the autumn the density of the residual quantity of locusts exceeds 450 per hectare, then a continuous investigation of clutches is undertaken, but if there are less than 450, then a selective count is made. From 1.5 to 9 samples per hectare are taken in large homogeneous areas under a continuous investigation, but from 9 to 18 samples under heterogeneous conditions and selective investigations.

In the spring of next year will be conducted an investigation with the purpose of establishing the percent of viable clutches, the periods of larva hatching, and the places of their accumulation. In addition intensive investigations will be conducted concerning the development of locusts. All these data will be utilizedain correcting the general plan for combative measures and the perfecting of the periods of their execution. Three cycles of observations are planned per season.

In the USSR as in Hsinkiang -- the Vighur Autonomuous Region of the Chinese People's Republic is distributed the western subspecies of the migratory locust, with one generation in the course of a year. However, in principle the general ecological relations of the dynamics of number of this subspecies are similar to those described for the Locusta migratoria manilensis Meyer. For this reason the prediction and combative measures plan in the USSR is also based on the system of investigation and accounting, and observations of the development and migrations of locusts. In each specific case there is also applied, as one of the known mechanisms, the dependence of multiplication and survival of locusts on the ecological factors.

Every year in the USSR a total of five planned reports on locusts are drawn up: two reports (autumn and spring) on clutches; three on the live insects under thinned densities. In addition,

special observations are established for individual swarms. In calculating the number of clutches, one sample is taken on the average per hectare. However, the system of distributing the tests is such that a sufficiently complete representation of the areas which are occupied by egg masses and the regularity of their distribution through the territory is obtained. On the whole this system of calculation provides the possibility for preventive measures against locusts.

We shall utilize material on the wheat midge (Sitodiplosis mosellana gehin) in order to become acquainted with the methods of predicting insects which have special feeding habits and only one generation in the course of a year. (Another species is found in the USSR -- Contarina tritici Kirby -- which is also found in hilly regions of China but which does not do significant damage there as it does here.) This wheat midge is distributed in China throughout flat, low-lying, well watered regions: in the basins of the 'eihe, (Nenhsi province), The and Lieh-ho (Honan Province), Yellow (Anwei Province), and Chia-ling-chiang rivers (the latter in the northern part of the Zechwan Province) and along the banks of the Yantse and Han-shui rivers. The ecology of the wheat midge and measures to combat it have been worked out by the Agricultural Scientific Research Institute of Northeastern China.

The wheat midge usually produces one generation per year, however, the larva which hibernate in the soil pupate and transform into the imago stage only under favorable temperature and moisture conditions. If these conditions are not favorable, the larva may remain in a dormant state for several years.

It has been determined that sandy and clayey soils are more favorable for the wheat midge than heavy clay and gravely soils. Soils with a moisture content of 14-16 percent are more favorable than those with a moisture content of 11 percent. Soils with a pH of 7-11 are favorable but soils with a pH which exceeds 12, or sour soils, are unfavorable for the existence of the larva of this midge.

The hibernating larva rise to the surface and pupate in the early spring under abundant precipitation. Here it has been established that the larva becomes active at a temperature of 10 degrees, and that a temperature of 15-20 degrees is optimum for the emergence of the midge.

The basic stages of work in making a prediction of the number and harmfulness of the wheat midge are the following:

1. Investigation and calculation of the density of the larvae in the soil. Area damage and the necessity for combative measures is determined in this manner. This work can be carried out in the autumn and spring.

2. Observation of pupation. If it is established that the larva transform into nymphs, the emergence of the midges may be expected in the next six or seven days. If the pupa are adults, then the emergence will take place in one to two days. This aspect is utilized to signal the beginning of combative measures.

3. Establishment of the periods and dimensions of possible harmfulness. The damage to the wheat depends on what phase of its

development coincides with the emergence of the midges: if in the earing phase one to two larvae are found in one flower husk then the damage will be very great. After the ripening of the grain even a large quantity of larva in each husk will cause only slight damage.

The cutworm moth (Laphygma exigua Hb.), which does serious damage to many crops in the USSR, produces several generations per year. Its number and harmfulness in a given vegetational season to a significant degree depend on the amount of over wintering pupae (the eggs, caterpillars, and adult insects cannot stand low temperatures and perish in winter). For this reason the most important criterion in solving the problems of possible cutworm moth harmfulness in the following year is the establishment of the phase of development of the basic mass of the species during the period when autumn and winter weather conditions are determined, with mean daily temperatures lower than 8-10 degrees (i.e. lower than the threshold of development). If the great majority of the insects went into hibernation in the pupa phase, then an increased number and hamrfulness of the moths can be expected in the following year.

The cotton boll weevil (Chloridea absoleta F.) is capable of enduring wintering conditions only as diapause pupa. For this reason it is necessary in the autumn to ascertain the percent of diapause pupa for predicting the number of the first generation for the spring of the following year. With this in mind, 300 pupæ are collected and maintained at temperatures of 23-25 degrees in the late autumn, when the mean daily temperatures drop lower than eight degrees. Within five days the percent of diapause pupa is determined by the following external signs: on the sides of the head, in the vicinity of the pigmentless eyes, are noticed four dark points which disappear at the beginning of development; the fat body in the diapause phase is large-laciniate and in the developed phase fluidized. This is well seen in the live pupa, as it is translucent.

Thus it can be seen from the examples given here that the methods of long-range prediction of insect multiplication are always diverse. This is connected also with the various possibilities of study of individual species and with the peculiarities of their biology. Data on their actual number and stational distribution in a given period are still at the present time the basis of solving the problem of the number of the majority of pests in the coming year or season.

A number of European countries do not make long-range predictions in general, because they still do not have sufficient foundations, but they plan plant protection activities proceeding from data on the actual presence of blights or by the average data on their harmfulness over many years. This is the attitude toward long-range predicting in Germany, Czechoslovakia, and other European countries. This can be fully justified, as the agriculture of these countries is highly intensive, embracing the cultivation of almost all the land capable of tillage; and the climate of these zones of Europe differs in relative stability. These two circumstances essentially stabilize the ecological conditions, and thus the development of blights and

diseases in various years. For this reason the accumulation of blights determines the level and dynamics of their number in a given year. (To a certain degree the work methods of the prediction services in these countries coincides with the hydrometeorological services, which derive the average indices of climatic factors over many years according to the indices of individual years). In several cases the influence of the activity of man, who breaks down the structure and mechanism of the development of established biocoenoses, gains special significance. And anomalies occur which are reflected in the number of individual species of pests.

As applied to the conditions in the USSR, such an attitude to long-range predictions would be unjustified. The climate of our country over a large part of its territory is strongly continental and very diverse. In various regions weather conditions are extremely changeable at various seasons of various years. The appearance of blights and diseases is connected with the weather conditions of individual years and the condition of the cultured and wild plants in these years. The very changeability in pest number and, very likely, the development of plant diseases in the conditions existing in our country are expressed significantly more dynamically than in countries of Eastern, Central, and Western Europe. This circumstance determines the great urgency of the problems of long-range prediction for our country. In addition, the large expanses of our country do not permit us to make detailed observations of the condition of blights and diseases to the degree that this is possible in countries of Eastern and Western Europe. All this requires us to combine to the maximum degree investigations and calculations of the spread of blights and diseases with the prediction of their further development and the extrapolations to large regions of material received at individual points. This considerably improves and makes easier the observation of blights and diseases.

In several branches of agriculture in the USSR (sugar beet growing, horticulture, viniculture, and in part, cotton and flax raising), plant protection measures are based predominantly on autumn and spring accumulations of blights and diseases. In part, this is explained by the poor development of long range prediction methods of the development of blights and diseases found in these crops, and partly by the important balancing of ecological prerequisites for the development of blights and diseases in various years by virtue of natural conditions and especially as the result of man's activity. For this reason the initial condition of blights and diseases of the crops mentioned above to a significant degree determines the dynamics of their development in a given season.

Scientific basis and Methods of Short-range Prediction of the Development of Plant Blights and Diseases

A great deal of attention is being given in all countries to short-range prediction of the development of plant blights and diseases. This is understandable. The utilization of established short-range predictions many times permits the number and volume of special crops to be preserved and their effectivity to be increased.

Various prerequisites for making short-range predictions are utilized, depending on the biological characteristics of the object:

a) the material of phenological observations, taking into consideration pest number or the intensity of the development of diseases in a given year;

b) calculation of the periods of development of blights in connection with temperature conditions, or on the basis of reporting the phenology of the development of the host plants;

c) data on the activity of pests, obtained by direct observation or by utilization of special traps.

The experience of the GDR deserves attention in regard to the organization of short-range prediction work. There is a technician in every populated point who, according to a clearly worked out, simplified set of instructions, gathers material which indicates the development, number and condition of the most significant blights and diseases. Every 5 or 10 days, the technicians report their observations in a uniform, very simple form to a regional point where specialists with secondary school qualifications are working. The latter report to the okrug [probably Bezirk] points. These points are in many respects comparable to the oblast [kray] prediction sectors in the USSR. The okrug points provide operational warning for production organizations, and at the same time accumulate valuable material for further scientific analysis. With regard to methodology, the entire prediction service of the GDR is subordinate to the Central Biological Institute of the Academy of Agriculture and Forestry.

Let us now look at some specific methods of short-range prediction which are applied in various countries and are based on the prerequisites described above.

We shall use the short-range prediction method used in the Chinese People's Republic for the cotton plant aphid (Aphis gossipii Glover) as an example of the utilization of materials on the actual phenology of a blight in a given year under a single calculation of the level of its number. Here the cotton plant aphid is very widely distributed but is considered especially dangerous in North, Northeastern, and Northwestern China. The biology of this aphid is complex. In its life cycle is noticed a mechanistic migration from several plant hosts to others; the parthenogenetic multiplication alternates with the gamogenetic. In China there have been discovered 113 species of plants which are hosts of the cotton plant aphid. These are divided into three groups: the plants on which the aphids hibernate, the intermediate hosts, and finally, the damaged plants. The mechanistic migration of the

cotton-plant aphid from the place of hibernation to the cotton plant takes place at the end of April; the greatest damage occurs from the last 10 days of May to the middle 10 days of July.

The number of the aphids depends primarily on weather conditions. A temperature of 16-22 degrees is favorable for multiplication, and a temperature of more than 25 degrees and relative humidity exceeding 75 percent suppresses its multiplication (the average daily temperature for a five day period according to data of meteorological stations). Damage by the aphid to the sprouts of the cotton plant in the early stages of development brings with it an essential decrease in the harvest, hinders the development of the plants and delays the ripening period of the capsules. Damage to the sprouts of the cotton plant at later stages does not cause much damage.

On the basis of what has been said above, the Chinese consider it especially important to make a prediction of the damage done to the sprouts in the early phases of development by the aphid. This prediction is worked out from a calculation of the amount of overwintering eggs of the aphid on plants and the percent of their survival. Survival depends on the temperature conditions in February and March. Frosts in this period are fatal to the aphid.

The cotton plants are examined every five days. On the basis of the calculation of the number of colonies of the aphids, the condition of the insects themselves, the temperature conditions and precipitation, the expected number and harmfulness of the aphids for the next 7-10 days is determined, and in accordance with this, measures for protecting the cotton plant from blights are planned. The percent of hatched aphids is determined by two methods. In typical hibernating places, 100 eggs are selected on the branches of herbaceous or arboraceous plants, then covered by a screen or gauze bag and observed for the amount of hatched aphids and then for their survival. The second method consists in the tabulating (in hibernating places) of eggs with ruptured shells, which provides information on the hatching of the aphids and all the nonviable eggs.

The disclosure of aphids on the cotton plant is carried out by taking into consideration individual sections of land, the agrotechniques, plant varieties, sowing periods and sprouts. Along a diagonal section, 50 plants are counted off. Up to the appearance of three leaves, the plants are observed as a whole for aphid content; after the appearance of three real leaves the upper leaf of the main stem is looked over, the second leaf in the middle [of the stem], and the third leaf in the lower part of the stem. The tabulated number of aphids is divided by three and multiplied by the total number of leaves on the plant (on the average out of 50 plants). This gives an idea of the number of aphids on one plant.

The number of adult, winged individuals and nymphs is determined from a calculation for 1,000 aphids tabulated individually on the upper, middle, and lower leaves. The count is carried out on leaves fixed in alcohol under binoculars in the laboratory.

An analogous example is the short-range prediction of the development of the sugar beet moth (Phthorimaea ocellatela), worked out in Rumania. The number of this pest in the spring depends essentially on hibernating conditions. Ithhas been established that in years of mild winters, when the temperature does not drop lower than plus 1 degree, 50-80 percent of the pupa and larva of the latest stage of growth are preserved on the plants remaining in the field. The mass multiplication of the sugar beet moth may result if in the autumn a high number of larva is present, in the winter periods of cold continue no more than 10-30 days, and in the spring, no more than 150 millimeters of precipitation occurs and the temperature fluctuates between 16 and 25 degrees. In this case three to four treatments with poison chemicals are made (one treatment for each generation). The periods of the treatments are determined by direct observation of thepphenologies of the pests -- of the time of the mass egg laying and the appearance of the first larvae. The latter is determined by examining 400 to 800 plants taken along a diagonal strip in the field.

In years when the development of the sugar beet aphid [sic] is poorly developed because of unfavorable hibernation in the winter (cold weather) and abundant precipitation in the spring, one spraying and in an extreme cased,two sprayings are made. Usually they are timed to the third or fourth generations.

In Bulgaria a reliable though labor-consuming system of short-range prediction is applied with respect to the development of the coddling moth (Carpocapsa pomonella L.), which considerably lightens the work of combatting this pest.

The development prediction for this moth is worked out at special observation points. Each point is supplied with live boxes of dimensions 70 x 35 x 35 centimeters. The eave-type covering and flat bottoms are of wood. The side walls are made up of thick screens; one wall has a door. The boxes are distributed in the crowns of trees. In them are contained the cocoons of the moths (1,000 and more) [in each box] to determine overwintering reactions and the development of the second generation. The material necessary for the observation is obtained by means of crimped paper belts. These are placed in trees no later than 15-20 June. The date of the formation of the first cocoons in the belts is established by means of daily observations. Within 10 days thereafter, the belts are removed and new ones put in their place (10 days usually pass from the moment of pupation to the emergence of the moth).

The removed belts are placed in the boxes. The belts are changed four or five times in all per season; the last time they are put up in the middle of August and taken off after apple-picking time.

In observing the development of the caterpillars and cocoons which are housed together with the belts in the box plantings, the course of development of the second generation is fixed, as well as the percentage of diapause caterpillars, the mortality of the caterpillars during the winter, and the course of the emergence of the moths.

The time of the first and subsequent sprayings are determined in accordance with the information received on the periods and course of emergence of the butterflies of the first and second generations. The amount of sprayings carried out against two generations are not uniform in the various regions of Bulgaria. At the present time, action is being taken from the degree of damage to orchards by the moths and the necessary amount of sprayings against each generation. Three regions have been established. In the first of these the degree of damage is the largest and three sprayings are made for each generation. In the second region the damage is less severe. Here two sprayings for the first generation and three for the second is recommended. In the third region the damage is still less severe and two sprayings for each generation is recommended.

The first spraying in the first region is carried out within 10-18 days (depending on temperature fluctuation and level) after the beginning of the flight of the butterflies of the first generation, and within 6-10 days after the beginning of the flight of the second generation. The subsequent two sprayings are carried out within 10-14 days, depending on meteorological conditions and the duration of the action of the chemicals.

In the second region the first chemical treatment against the first generation is applied in the period when butterfly emergenge reaches 30-35 percent, and spraying for the second when it reaches 80-85 percent; the second generation is treated similarly to that of the first region.

In the third region, the first spraying against both generations is carried out when the emergence of the butterflies reaches 30-35 percent, and the second spraying when the emergence reaches 80-85 percent.

Direct observations are utilized in Czechoslovakia also for short-range predictions in which periods to combat the Colorado potato beetle (Leptinotarsa decemlineata) are determined. For this, special netted, cylindrical boxes 45-50 centimeters in diameter and 50-60 centimeters in height are used. These boxes have an open bottom and a removable roof, (the lower part of the box is driven into the soil). Here the percent of overwintering beetles in the soil and the period of their emergence to the surface is determined.

From 100 to 200 caught beetles are housed in the autumn in each live box and are fed potato tops. The behavior of the beetles and their going into hibernation in the soil is observed daily, along with the observation of the meteorological conditions. In the second half of October, when all the beetles have gone into hibernation, the roofs of the boxes are removed and they are left open for the winter. In the spring, just before the appearance of the beetles on the surface, when the temperature of the soil at a depth of 10 centimeters approaches 9-10 degrees, one box is removed and the percentage of surviving individuals is determined by examining the soil. During this time, the second box is covered with its roof. The periods of the emergence of overwintering beetles from the soil is determined by means of daily

observations. In addition, observations are made on the progress of multiplication and the development of larva. The warning to begin combative measures is given when the larva are five days old.

We can use the method of short-range prediction applied in China for the piriculariosis of rice (Piricularia oryza Bri. et Cavara) as an example of predicting the appearance of plant diseases on the basis of reporting the phenology of the development of plants and the presence in nature of pathogenic agents. It has been established that rice yields are lowered mainly by the piriculariosis of the panicles [metelka]. The appearnace of this disease depends on the tasseling [vybrasyvaniye] of the panicles, on the presence during this time of the disease on the leaves, and on the meteorological conditions. Tardiness in the tasseling of the panicles, especially more than 10 days, leads to a mass appearance of the disease. The development of the disease is aided by temperatures between 19-24 degrees and rainy weather extending to 10-15 days or to the formation of the panicles. As a result, special experimental research has established that the mentioned meteorological conditions are not optimum for the development of the spores of the pathogenic agents of the disease, but that they essentially lower the resistance of the plant to the disease. Proceeding from these circumstances, the probable development of piriculariosis is predicted for 10-15 days up to the appearance of the panicles on the rice, and the necessary preventive measures are then undertaken.

The determination of the periods of the phenological development of blights and diseases, depending on the sum of temperatures, can be shown in a number of examples. In Rumania, along with other methods, the prediction of the periods of development of the leaf-roller (Tortricidae) by tabulating the sumeof effective temperatures is utilized. The threshold of development amounts to 12 degrees for the grape leafroller and the sum of the temperatures, 150 degrees. During this time, spraying is carried out. This period can be forecast for 7-10 days by judging meteorological conditions.

The periods for combatting the larva of the summer generation of the San Jose scale (Apsidiotus perniciosus) is determined in Rumania by the same method of temperature condition. The threshold of its development equals 7 degrees and the sum of effective temperatures is 480 degrees.

The connection of the incubation period duration with the temperature of the air is mainly taken into consideration in short-range predictions of grape mildew. The starting point is the establishment of the first infecting by the mildew, whose indices are attendant upon the fall of abundant precipitation and the presence of an average daily temperature of no less than 11 degrees. The duration of the incubation periods is determined by the sums of effective temperatures. For the mildew this sum is equal to 60 degrees, with a threshold of development at 8 degrees.

Short-range predictions on the basis of calculating the duration of the incubation period are also worked out for potato phytophores, grape fungus, various species of grain rusts, and the cercosporiasis of sugar beets. It is true that it was almost unanimously agreed at the Conference that the method of tabulating the sums of effective temperature frequently leads to mistakes. In particular, many data were obtained in Rumania which indicate that the sum of effective temperatures and the general duration of the incubation period for grape mildew essentially differ, depending on the 24-hour fluctuations of the temperature and temperature level.

Thus in 1955 at the Experimental Vinicultural Station in Dragashan' the application of the artificial method of infection made it possible to determine that the incubation period was terminated under the sums of effective temperatures of from 33 to 111.6 degrees. In two cases, amounts closer to 61 degrees were noted, which were indicated as a norm by D. D. Verderevskiy; in five cases the amounts were less, and in seven greater. Similar material was obtained at the Cragunelul Experimental Vinicultural Station.

In the majortiy of countries the main method of short-range prediction of the development or activity of blights and diseases for the present remains the method of direct observation or calculation with the help of various detectors. In Czechoslovakia, for example, observations of the development of diseases in sown areas by sections with a knowledge of the infected soil is utilized for predicting the periods when spraying against the potato phytophore is to be carried out. In each natural-economic region experimental inoculation is carried out in infected soil. When in this section the first signs of the appearance of the disease are evident, the warning is given to carry out preventive treatment in the entire region in the course of seven days.

In the GDR the methods of direct observation for determination of the necessity and the periods of carrying out protective measures are applied in regard to potato phytophores, grape mildew, rape plant Nitidulidae, rape stem snout beetle, cabbage stem gall weevil, and also in determining the various stages of development of the rape plant fleabeetle [rapsovaya bloshka], the Colorado potato beetle, the cabbage butterfly, the sugar beet bug, and the wild turnip sawfly. In all cases, in the soil or on the plants, the insects are tabulated, the signs of the disease are ascertained, and the intensity of its development determined. In addition there is ascertained from materials of the past years what sort of actual damage there can be to crops in the presence of a given number of pests and in the intensity of the development of diseases. The necessity for preventive measures in a given year or seqson is determined on the basis of these comparisons with past years. This method is not thorough, as the significance of blights and diseases for plants in a given year depends not only on their quantity and the intensity of development, but also on the condition of the plants, which in turn depends on agrotechnical and weather conditions. Nevertheless this method is widely utilized.

Periods of combatting the cherry fruit fly, which does considerable damage to cherries in Bulgaria, is determined on the basis of calculating the beginning of its flights. For this, glass traps are set up in the cherry orchard on 10 or more trees (here an attempt is made to include all existing varieties). Into the traps is poured a 10 percent solution of sugar syrup with a 0.5 percent admixture of ammonium sulfate. This solution attracts the fly to the traps which are set out in the middle of April. The number of trapped flies is counted every day; once every two days more solution is added. The treatment of the orchards with poison chemicals is carried out within 10-14 days after the beginning of the flights of the flies. If the intensity of the flights after the treatment of the orchards does not fall off, then the warning is given for a necessary second treatment.

As is known, the collecting of insects with lures is widely applied in the work of the observation points of various countries. In the GDR insects are collected widely with bowls painted a yellow color and attract insects of many species. Water is poured into the bowl and a spread [rastekatel'] or insecticide is added to it. Automatic light traps are used in the GDR to collect the coddling moth which are attracted by ultraviolet rays. The ultraviolet radiation of the special lamps set up at a height of two meters from the ground is directed by a reflector to a screen made of a small lattice network covered by a sticky substance. The lamps operate two hours a night and are automatically switched off. Such traps may be utilized to obtain data on the specific composition of insects and on their flight activity in various regions of the country. Traps in the form of glass smeared with vaseline or a mixture of glycerin with gelatin are also used for spores. As used in the GDR, these spore traps permit the spread of such diseases as the potato phytophore to be determined. The glass is usually changed every 24 hours and is then examined under a microscope. However, if a suction pump is utilized, which conducts a sufficiently large amount of air to the trapping glass, it is sufficient to trap the spores during one hour a day.

In spite of all the labor necessary in the methods of direct observation and calculation, they are at the present time the most reliable for the short-range prediction of the development of blights and diseases.

Conclusions

In presenting the results of what has been mentioned above, we must emphasize the following:

1. The scientific basis for predicting the development of blights and diseases and the practical ways of rationally utilizing this basis is being worked on at the present time intensively in all countries.

2. The elaboration of the methods of long-range prediction of the appearance of blights is the most complex. However, as has been

shown by experience in a number of countries, the practical necessity for annual long-range predictions arises only for a comparatively limited number of blights. In the majority of cases, short-range predictions of the development of blights and diseases has practical significance of the first degree for successful plant protection.

3. Methods of long-range prediction of small rodent numbers (field mice, gerbils) have to the present time been most intensively developed. The mechanism has been established of the forming of the viability of populations of individual species of rodents under the influence of ecological conditions and their significance for the forecasting of alterations in the spread and number of pests. These methods of research are also being applied to working out methods for the long-range prediction of the multiplication of harmful insects. The given direction permits us to obtain criteria for predictions, on the basis of which is supported the easily obtainable analysis of ecological conditions for a past period of time.

4. The disclosed dependence of the development, multiplication, and ability to survive of individual species on the specific combining of ecological factors in different seasons of the year is utilized most frequently of all for the purpose of working out methods for predicting insect numbers. The predictions of the appearance of individual species is compiled through taking into consideration these data and materials of special investigations, carried out according to an established system. The given trend permits us to make predictions which are mainly concerned with those conditions which may take shape in the future, but this is not always possible.

5. Practical present predictions of the appearance and spread of blights and diseases is being worked out on the basis of directly determined presences, spreads, and phases of development of the object to be predicted in a given period of time. In connection with this, work which also permits the most objective and complete disclosure of their actual spread and condition in nature must be developed along with the research which reveals the authentic mechanisms of the dynamics of the spread and development of individual species.

6. The volume of experimental work exchanged among various countries in the prediction of blights and diseases will accelerate the solving of this complex biological problem and will make easier the utilization of practical conclusions in perfecting the system of plant protection activities.

10,276

- END -